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Steen

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(54) **HYDRAULIC PUMP WITH BALL JOINT SHAFT SUPPORT**

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(52) **U.S. Cl.** **417/269**; 91/499
(58) **Field of Search** 417/269; 91/499; 92/74; 74/60

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,807,283	*	4/1974	Alderson et al.	417/269
4,007,663	*	2/1977	Nagatomo et al.	91/499 X
4,352,637		10/1982	Weisenbach .	
4,757,743		7/1988	Tovey .	
4,771,676	*	9/1988	Matsumoto et al.	91/499 X
5,011,377	*	4/1991	Sagawa et al.	417/269
5,165,321	*	11/1992	Arimoto et al.	91/499
5,271,285		12/1993	Silliman, Jr. et al. .	
5,622,097	*	4/1997	Martensen et al.	74/60 X
5,681,149		10/1997	Weatherly .	
5,813,315	*	9/1998	Kristensen et al.	417/269 X
6,036,374	*	3/2000	Fisher et al.	91/499 X

OTHER PUBLICATIONS

Shigley, Joseph Edward; Mechanical Engineering Design; 1977; McGraw–Hill (New York); 3rd Ed.; p. 322.*

* cited by examiner

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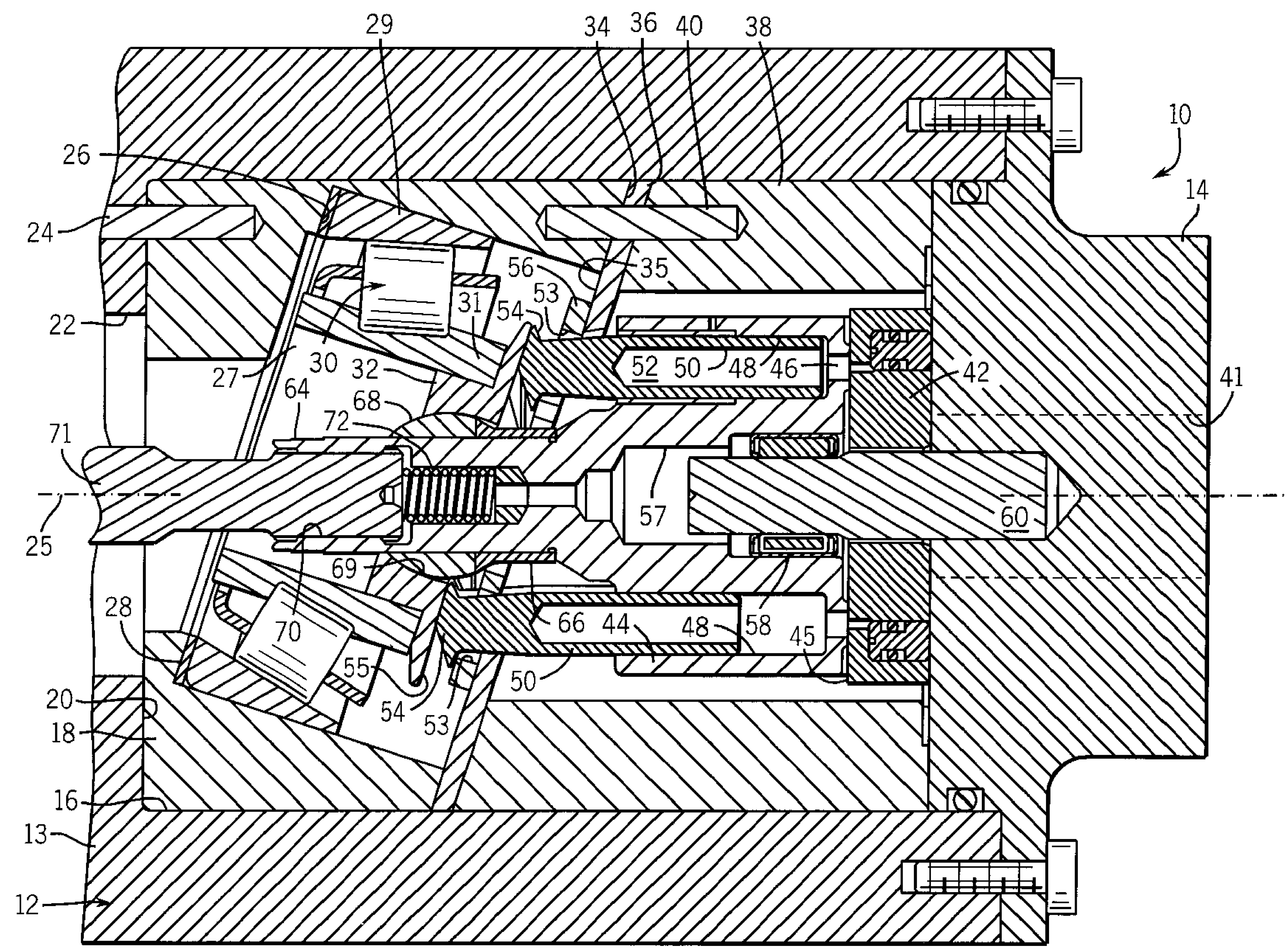
(57) **ABSTRACT**

An in-line axial piston hydraulic pump has a cylinder block with a plurality of bores in which separate pistons slide. The cylinder block is supported on one side by a bearing and axle arrangement. The other side of the cylinder block has an integral shaft with a ball that is received in a spherically concave socket coupled to the housing. The socket provides a drive surface that is non-orthogonal to the rotational axis of the cylinder block and the pistons ride against that surface. The engagement of the pistons with that socket surface produces the sliding movement of the pistons within the bores and thus the pumping action.

18 Claims, 2 Drawing Sheets



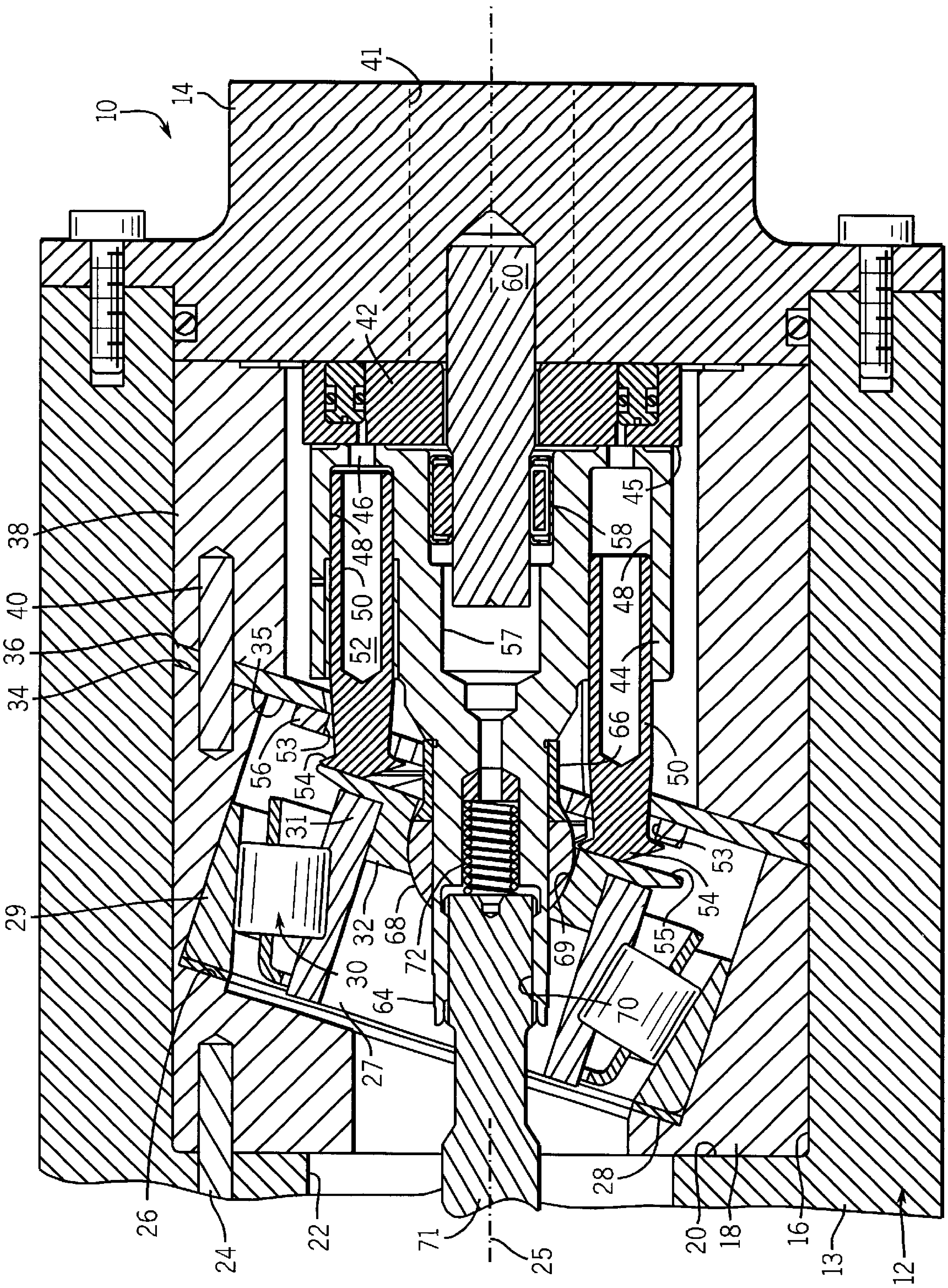

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FIG. 1

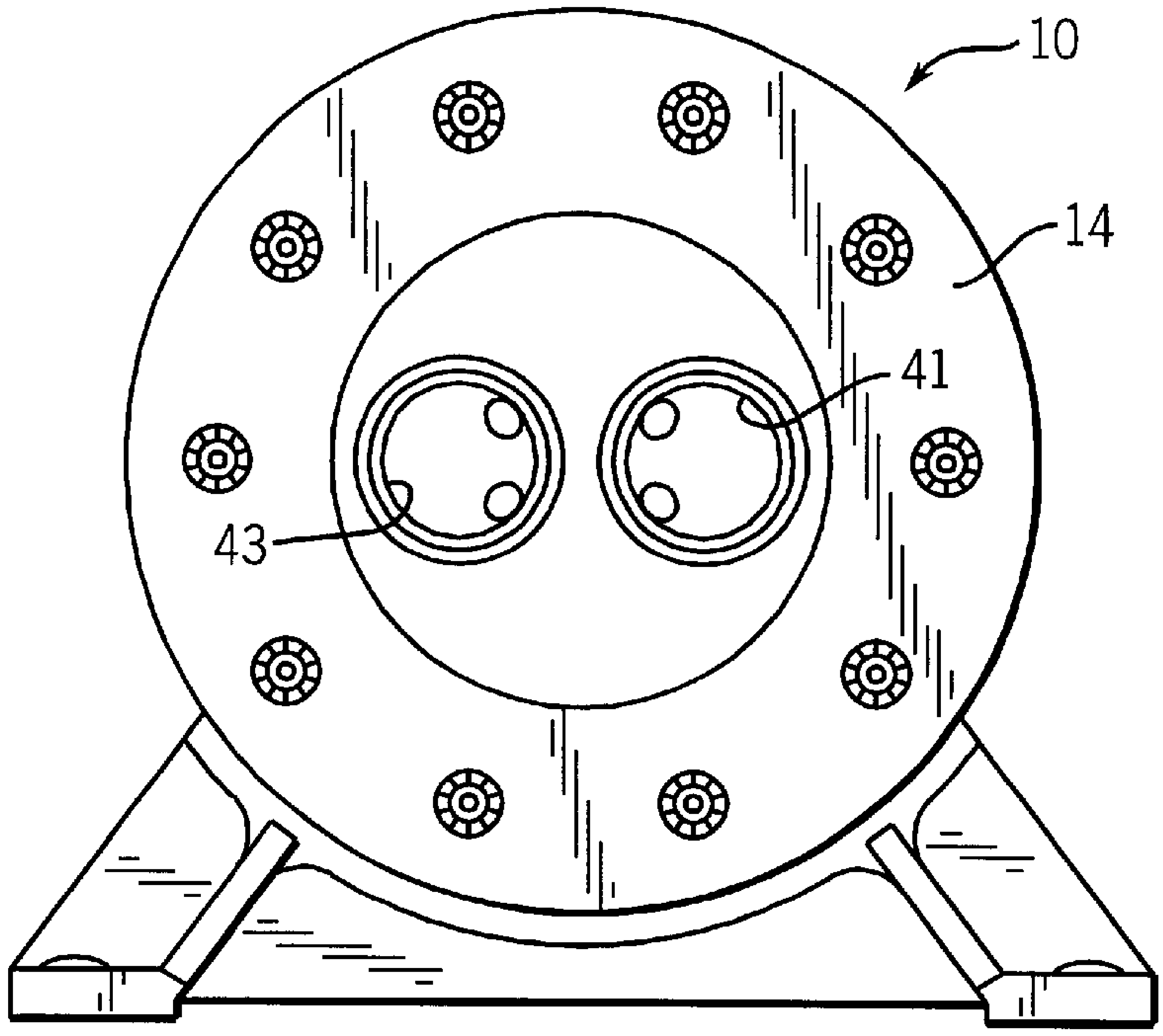

FIG. 2

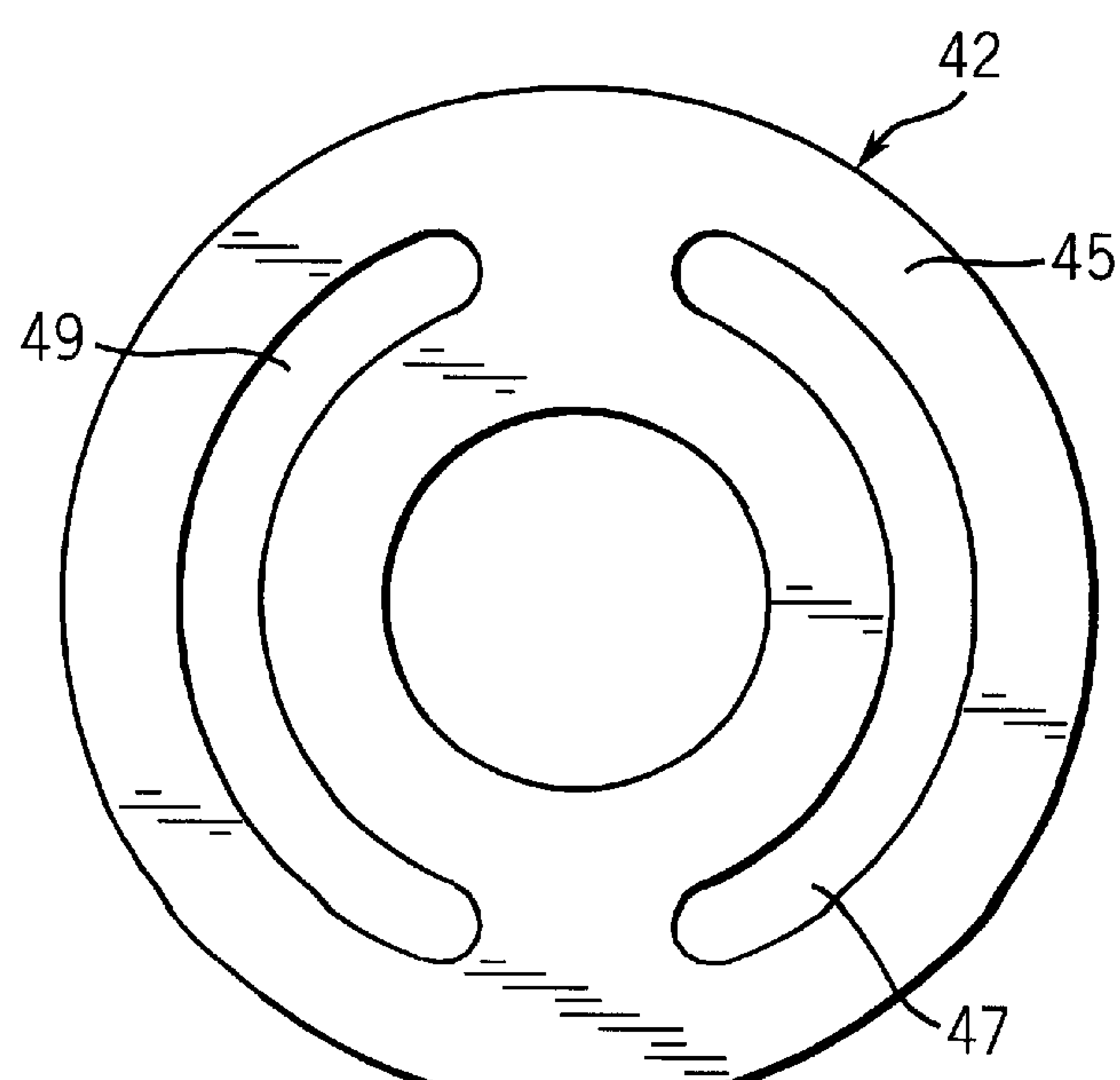

FIG. 3

HYDRAULIC PUMP WITH BALL JOINT SHAFT SUPPORT

BACKGROUND OF THE INVENTION

The present invention relates to hydraulic pumps, and in particular to in-line axial piston pumps.

Conventional in-line axial piston pumps have a plurality of pistons in multiple bores of a single piece cylinder barrel. The cylinder barrel is keyed to the drive shaft and is rotated by a prime mover, such as an electric motor. The cylinder barrel and the pistons are parallel to the drive shaft. As the cylinder barrel rotates within the pump housing, the pistons follow an inclined surface of a swash plate thereby reciprocating in their bores. The reciprocal motion of the pistons produces a pumping action.

The swash plate typically is a steel ring that is held at an acute angle with respect to the axis of the drive shaft. During one-half of the shaft rotation, each piston is pulled from its bore which draws fluid into that bore. Upon reaching the maximum extended position, the piston starts traveling along a portion of the inclined swash plate which pushes the piston into the bore thereby forcing the fluid to flow out of the pump.

The displacement of a given pump is determined by the number of pistons, each piston's diameter and the length of the stroke. The steeper the angle of the swash plate, the longer the piston's stroke. In a variable displacement pump, the angle of the swash plate can be changed dynamically to alter the stroke and thus the pump displacement.

Pumps of this design are well known and are commonly used in aircraft hydraulic systems. In aircraft applications, the size and weight of the pump are critical. Therefore, any improvement which reduces these factors will have benefit in aircraft usage.

SUMMARY OF THE INVENTION

A hydraulic pump according to the present invention includes a housing that has an inner chamber. A cylinder block with a plurality of piston bores is supported within the inner chamber for rotation about a longitudinal axis. During that rotation each piston bore alternately communicates with a fluid inlet and a fluid outlet in the housing. The cylinder block comprises a spherically curved element and a coupling for a drive member that produces rotation of the cylinder block. A bearing rotationally couples the cylinder block to the housing.

A socket is rotationally coupled to the housing, preferably by another bearing. The socket has an aperture with a surface that mates with the spherically curved element of the cylinder block. A drive surface, provided on the socket, is non-orthogonal to the longitudinal axis. A different one of a plurality of pistons is slidably located within each piston bore and has a head which engages the drive surface of the socket.

The drive member produces rotation of the cylinder block about the longitudinal axis. The socket rotates about an axis that is non-coaxial with the longitudinal axis. Thus as the cylinder block rotates, the pistons reciprocate into and out of the bores providing pumping action. As that rotational movement occurs the socket wobbles across the surface of the partially spherical element of the cylinder block.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a cross-sectional view of a hydraulic pump according to the present invention;

FIG. **2** is a plane view of an end of the hydraulic pump; and

FIG. **3** is a plane view of a valve plate shown in FIG. **1**.

DETAILED DESCRIPTION OF THE INVENTION

With reference to FIG. **1**, a hydraulic pump **10** has a housing **12** formed by a body **13** with an open end that is closed by an end cap **14** held in place by a plurality of machine screws. The body **13** has an inner chamber **16** which contains the components of the pump. An angle block **18** is inserted into the inner chamber **16** resting against an inner wall **20** having a central opening **22**. A locking pin **24** extends into holes in both the body **13** and the angle block **18** to prevent the latter component from rotating. The angle block **18** has a bearing cavity **27** with an inner surface **26** which is non-orthogonal with respect to the longitudinal axis **25** of the inner chamber **16**. A washer **28** is sandwiched between the angled surface **26** and an outer race **29** of a tapered roller bearing **30** located in the bearing cavity **27**. An annular socket **32** engages the inner race **31** of the tapered roller bearing **30**.

The angle block **18** has an end surface **34** in a plane that is non-orthogonal with respect to the longitudinal axis **25** of the inner chamber **16**. An annular retainer plate **36** is held against that end surface **34** by a tubular sleeve **38** which abuts the end cap **14**. The retainer plate **36** and the sleeve **38** are prevented from rotating by a second locking pin **40** which extends through apertures in both of those elements and into an aperture in the angle block **18**. The retainer plate **36** provides a substantially planar retainer surface **35** that is non-orthogonal to the longitudinal axis **25**.

The fluid inlet **41** and outlet **43** for the pump are formed in the end cap **14** as shown in FIG. **2** and communicate with a conventional floating valve plate **42** which abuts the end cap **14** within chamber **16**. The valve plate **42** has conventional kidney shaped inlet and outlet slots **47** and **49**, shown in FIG. **3**, which open into the inner chamber **16** of the body **13**. Referring again to FIG. **1**, a cylinder block **44** abuts a flat surface **45** of the valve plate **42** having the inlet and outlet slots **47** and **49**. The cylinder block **44** has a central aperture **57** with a roller bearing **58** located therein. An axial pin **60** fits within the roller bearing **58** extending outward from the cylinder block **44** through a central opening in the valve plate **42** and into a receiving aperture in the end cap **14**. As will be described, the prime mover for the pump causes the cylinder block **44** to rotate on the axle pin **60**.

The surface of the cylinder block **44**, which abuts the valve plate **42**, has openings **46** into a plurality of piston bores **48** located axially around the axle pin **60**. A typical pump may have nine bores with only two bores being visible in the drawing. Within each bore **48** is a separate piston **50** that has an internal cavity **52** with an opening facing the cylinder block passage **46**. Each piston has a head **54**. The pistons extend through a central aperture in the retainer plate **36** and through individual apertures **53** in a hold down plate **56** which rests against the angled retainer surface **35** of the retainer plate. Each piston has a head **54** on the remote side of the hold down plate **56** and the end surface of the piston heads abut a drive surface **55** of the socket **32** that is angled with respect to the longitudinal axis **25** of the pump mechanism. As will be described, rotation of the pump components causes the pistons to ride against the angled drive surface **55** of the socket which pushes the pistons **50** into their respective bores **48** during half of the rotation cycle. During the other half cycle of rotation, the hold down plate **54** engages the piston heads and pulls the pistons **50** out of those bores.

The cylinder block **44** has an integral shaft **64** projecting from the side that is remote from the valve plate **42**. That shaft **64** extends through the central openings in the retainer plate **36**, the hold down plate **56** and the socket **32**. A socket collar **66** is placed around the shaft abutting the main body of the cylinder block **44**. The collar **66** engages a ball **68** that has an aperture through which the shaft extends. The spherically curved surface of the ball rests in a mating relationship within a spherically curved concave aperture **69** of the socket **32**, thereby supporting the ball **68** and the shaft **64** of the cylinder block **44**. By supporting the shaft of the cylinder block **44** with a spherical ball and socket arrangement, the first bearing **30** receives the shaft load and the side loads from the pistons. This arrangement also enables the number of bearings to be reduced from previous in-line axial piston pump designs. Although the ball **68** is shown as a separate component from the cylinder block, the ball could be formed integrally on the cylinder block shaft **64**. Therefore, as used herein the cylinder block **44** is considered as including the ball **68** even though they may be separate components and even though the cylinder block shaft **64** may be able to rotate independently of the ball.

The shaft **64** of the cylinder block **44** has a central aperture **70** with inner splines. The aperture receives the end of a splined drive shaft **71** which extends from a motor or other type of prime mover for the pump **10**. The splines of the drive shaft **32** and the shaft aperture **64** mesh so that the cylinder block **44** rotates with the drive shaft. A helical spring **72** is located within the aperture **70** of the cylinder block shaft **64** and biases the drive shaft **71** outwardly from that shaft.

Upon rotation by the prime mover, the drive shaft **71** transfers rotational force to the shaft **64** which causes the integral cylinder block **44** to rotate against the surface **45** of the valve plate **42**. Rotation of the cylinder block **44** carries the pistons **50** in a circular motion. That motion is transferred to the socket **32** by friction between surfaces of the socket **32** and the piston heads **54** and ball **64**. Because the socket engages the inner race of the tapered roller bearing **30** which provides a low friction rotational support, the socket **32** tends to rotate with the cylinder block **44**. However, rotation of the socket **34** is about the axis of the inner race **31** of the tapered roller bearing **30** which axis intersects the longitudinal axis **25** of the cylinder block at an acute angle. Thus as the cylinder block rotates, the pistons **50** are reciprocally pushed into and pulled out of the respective bores **48** by the angular rotation of the socket **32**. For example, as shown in the drawing the lower piston **50** has been pulled outward through its respective bore, whereas the upper illustrated piston **50** has been pushed almost fully into its bore **48** by the socket **32**. This reciprocal movement of the pistons produces the pumping action.

As the inner components of the pump **10** rotate, the socket **32** wobbles about the ball **68**. Specifically, the upper most portion of the socket **32**, in the orientation of the device in FIG. **1**, has been pushed rightward so as to nearly abut the socket collar **66**, whereas the lower portion of the socket **32** has moved away from the socket collar **66**. When the device rotates 180° from the position illustrated in FIG. **1**, the portion of the socket **32** which had been uppermost has rotated into the lower position and wobbled on the ball **68** away from the socket collar **66**. Similarly, in this 180° position, the portion of the socket **32** which was previously in the lowermost location now has rotated into the uppermost position where it nearly contacts the socket collar **66**.

By utilizing the ball and socket arrangement of the present invention, only two bearings **30** and **58** are required. In addition, the overall axially length of the pump has been reduced. Thereby, conserving both weight and space.

What is claimed is:

1. A pump for hydraulic fluid, said pump comprising:

a housing having a fluid inlet and a fluid outlet with a longitudinal axis both of which opening into an inner chamber;

a cylinder block with a plurality of piston bores and supported within the inner chamber for rotation about a longitudinal axis, wherein during rotation each piston bore alternately communicates with the fluid inlet and a fluid outlet, the cylinder block including an element with a spherically curved surface and further including a coupling for a rotating drive member;

a socket having an aperture with a curved surface that mates with the spherically curved surface of the element of the cylinder block, the socket having a drive surface that is non-orthogonal to the longitudinal axis;

a plurality of pistons each slidably located within a different one of the plurality of piston bores and having a head which engages the drive surface of the socket; and

a coupling bearing which extends between the housing and the socket to support the cylinder block axially for rotational movement within the inner chamber.

2. The pump as recited in claim **1** further comprising an angle block located within the inner chamber and forming a bearing cavity; and the coupling bearing within the bearing cavity and engaging angle block and the socket.

3. The pump as recited in claim **2** wherein the coupling bearing rotates about an axis that is non-coaxial with the longitudinal axis.

4. The pump as recited in claim **1** further comprising another bearing rotationally coupling the cylinder block to the housing.

5. The pump as recited in claim **1** further comprising a hold down plate having a plurality of apertures though which the plurality of pistons extend, wherein the hold down plate abuts a retainer surface of the housing which is non-orthogonal to the longitudinal axis.

6. The hydraulic machine as recited in claim **5** wherein the retainer surface is substantially parallel to the drive surface of the socket.

7. A pump for hydraulic fluid, said pump comprising:

a housing having an inner chamber formed by an inner wall;

an angle block within the inner chamber proximate to the inner wall and having a bearing cavity;

a first bearing within the bearing cavity and having a first race engaging the angle block, the first bearing comprising a second race that rotates about an axis that is non-coaxial with the longitudinal axis;

an annular socket engages the second race of the first bearing, the annular socket having an aperture formed by a curved concave surface and having a drive surface;

a cylinder block with a plurality of piston bores and supported within the inner chamber of the housing for rotation about a longitudinal axis, the cylinder block including a partially spherical member within the aperture of the annular socket and including a coupling for a drive shaft that produces rotation of the cylinder block; and

a plurality of pistons each slidably located within one of the plurality of piston bores and having a head which engages the drive surface of the annular socket.

8. The pump as recited in claim 7 wherein the drive surface of the annular socket is substantially planar.

9. The pump as recited in claim 7 wherein the first bearing is a tapered roller bearing.

10. The pump as recited in claim 7 further comprising a second bearing coupling the cylinder block to the housing.

11. The pump as recited in claim 7 further comprising a second bearing coupling that engages the cylinder block; and an axial pin that engages the second bearing and the housing.

12. The pump as recited in claim 7 further comprising a hold down plate having a plurality of apertures through which the plurality of pistons extend, wherein the hold down plate abuts a substantially planar retainer surface of the housing which retainer surface is non-orthogonal with respect to the longitudinal axis.

13. A pump for hydraulic fluid, said pump comprising:

a housing having an inner chamber formed by an inner wall with an opening for a drive shaft, the inner chamber having a longitudinal axis;

an angle block within the inner chamber proximate to the inner wall and having a bearing cavity;

a first bearing within the bearing cavity and having a first race and a second race, wherein the first race engages the angle block;

an annular socket engages the second race of the first bearing, the annular socket having an aperture formed by spherically concave surface and the annular socket having a substantially planar surface that is non-orthogonal to the longitudinal axis;

a cylinder block with a plurality of piston bores and rotationally supported within the inner chamber of the housing, the cylinder block including a spherically curved member within the aperture of the annular socket and including a coupling for the drive shaft that produces rotation of the cylinder block about the longitudinal axis; and

a plurality of pistons each slidably located within one of the plurality of piston bores and having a head which engages the substantially planar surface of the annular socket.

14. The pump as recited in claim 13 wherein the first bearing rotates about an axis that is non-coaxial with the longitudinal axis.

15. The pump as recited in claim 13 wherein the first bearing is a tapered roller bearing.

16. The pump as recited in claim 13 further comprising a second bearing coupling the cylinder block to the housing.

17. The pump as recited in claim 13 further comprising a second bearing coupling that engages the cylinder block; and an axial pin that engages the second bearing and the housing.

18. The pump as recited in claim 13 further comprising a hold down plate having a plurality of apertures through which the plurality of pistons extend, wherein the hold down plate abuts a substantially planar retainer surface of the housing which is non-orthogonal with respect to the longitudinal axis.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,287,086 B1
DATED : September 11, 2001
INVENTOR(S) : Kevin W. Steen

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 4,
Line 42, replace claim 6 with the following:
-- 6. The pump as recited in claim 5 wherein the retainer surface is substantially parallel to the drive surface of the socket. --

Signed and Sealed this

Twenty-fifth Day of June, 2002

Attest:

JAMES E. ROGAN

Attesting Officer *Director of the United States Patent and Trademark Office*